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PRODUCT STRUCTURING IN BUSINESS INNOVATION

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Abstract

In order to be competitive industrial companies need to have effective business processes. A business process is an assembly of connected activities and is designed to create value for customers. In this paper the business process is composed of four sub-processes according to four phases in the product life cycle. The activities are carried out within the processes.

An industrial company can be regarded as a business system, which is composed of sub-systems. The business sub-systems are representing different perspectives on the business, inside and outside the company, and can be denominated market, innovation, supply and service.

The innovation system can be further decomposed into sub-systems. By regarding these sub-systems as different views of the innovation system, and handling them as domains, theories and methods from the engineering design area can be utilized for business innovation and product platform development. For the navigation within and between the domains (sub-systems) a design tool called *Interaction Mechanism* is used for innovation in the business system including transformation of information. The results of the interactions can form the information content for the business and the product platform as demand/offer structure, function structure, realization structure, production structure and maintenance structure.

Business innovation covers the area from business and product idea to business operation and product maintenance, and includes customer demands and solutions. The main part of business innovation is development of the product platform including product and support structures. Product variants are created and realized by various configurations of products and production systems.

Keywords: Product structuring, product platform development, product life cycle modelling, innovation methods, integrated product and production development.

1 Introduction

Product structuring and product life cycle modelling are important parts in the development of product platforms for engineering and manufacturing companies. During development the product should be structured according to different needs and views from inside and outside the company, as customer, market, function, design, supply, maintenance and so on. Industrial companies need complete product life cycle models from product idea to product termination for their business innovation and operation.

1.1 Objectives

The objectives for this research are to create business innovation models and tools for engineering and manufacturing companies with the purpose to support them to be effective and competitive in development, manufacturing and maintenance of mechatronical products.

1.2 Methods

Observe-Analyze-Synthesize-Represent-Validate
The research work is structured according to Object, Subject and Theory and performed by Observation, Analysis, Synthesis, Presentation and Validation.
The Object of observation is the business innovation. The Subject is the researcher. The Theory is the model that is presented and validated.

The Theory of Domains
The Theory of Domains [1], [2], [3], [4] is based on four different views of a mechanical system and leads to a genetic model for the results of the design task, the chromosome model. Each way of looking at things is called a domain. The domain model can be regarded as a basic map, on which it is possible to chart the progress of the design task.

Axiomatic Design
Axiomatic Design [5], [6], [7], [8] is a method that provides the designer with a logic approach to design tasks. Thus, the designer will get a good structure and documentation at all hierarchical levels of the design object regardless of the extent of the design task.

2 Industrial Systems and Processes

2.1 Innovation and production

Human activities have to consider preparation first and then execution. In industrial processes, preparation is innovation and execution is operation e.g. production as in Figure 1. In the innovation process, products and production systems are created [9], [10]. The production system is initiated from customer orders and cultivates material to carry functions appreciated by the customers. The decisions in the innovation process are defining the products and the operative processes within the business process under the business strategy.

Innovation is primarily an information and knowledge development process employing our cognitive and visionary creative abilities. This requires specific competence and can be enhanced from problem solving support. Creativity, quality and productivity are important elements in industrial development and production [11], [12].

Sustainable industrial innovation and operation must satisfy customers, shareholders and employees without harming nature or be hazardous to humans.

Innovation has to start with accurate definitions of requirements and needs. Innovation processes have to be guided through accurate and competent decisions based upon firm criteria focusing quality and productivity. Competent decisions are demanding and require strict and strategic definition of competence requirements.

Good decisions require defined goals. In industrial innovation processes, goals must be defined based upon knowledge about customers´ needs as well as expectations from shareholders and employees. If we could base our decisions more on scientific theory and less

on belief and heuristic experiences it should be possible to increase our creativity and effectivity as well as our ability to meet defined requirements.

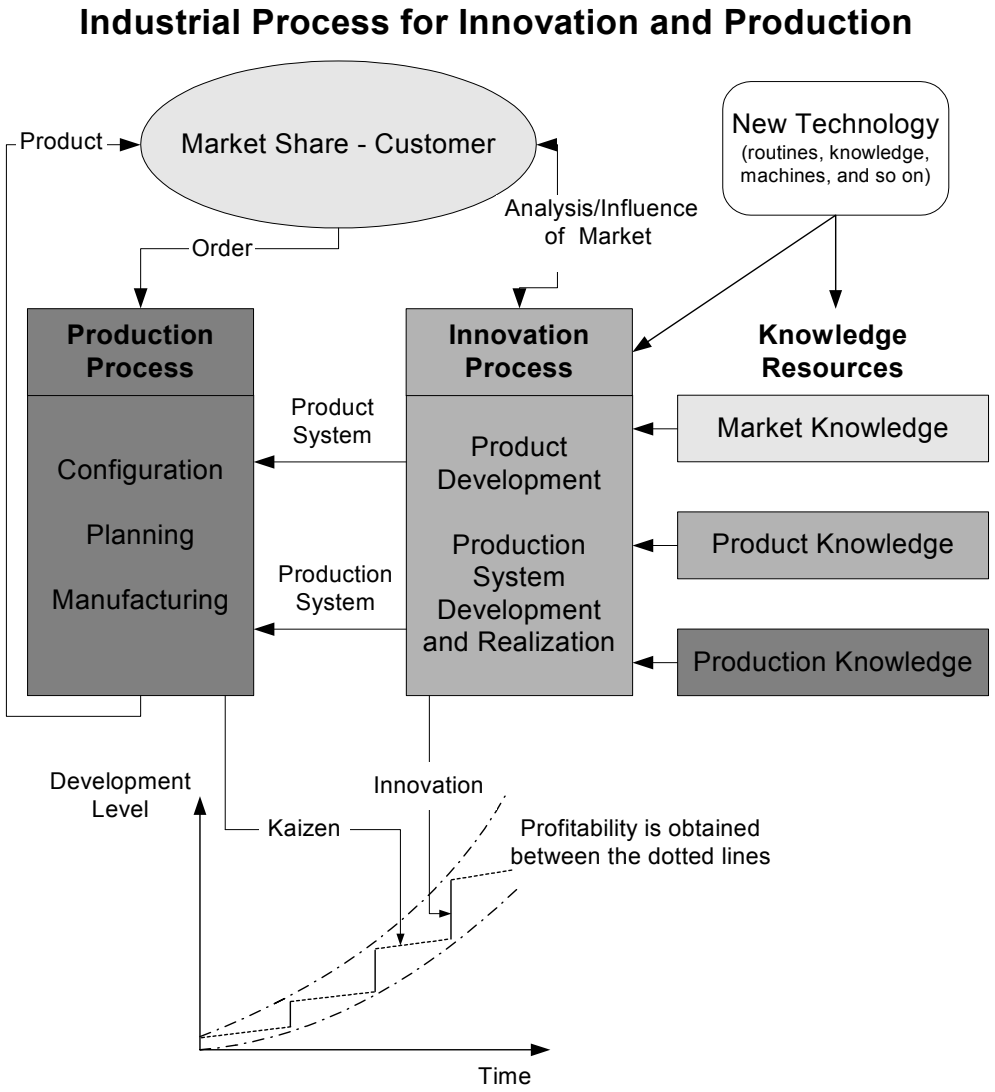

Figure 1. Industrial Process contains Innovation Process and Production Process

2.2 Inherent Logic of the Innovation Process

There are three complementary worlds, which are essential besides the real world in an innovation or a development system. These worlds are the *model world*, the *decision world* and the *human competence world*, Figure 2. The innovation process can be understood as combining the decision world with the human competence world and the modelling world [9]. The decisions in the innovation process are of course directly influencing the result. The decision criteria therefore have to be directly related to quality and productivity.

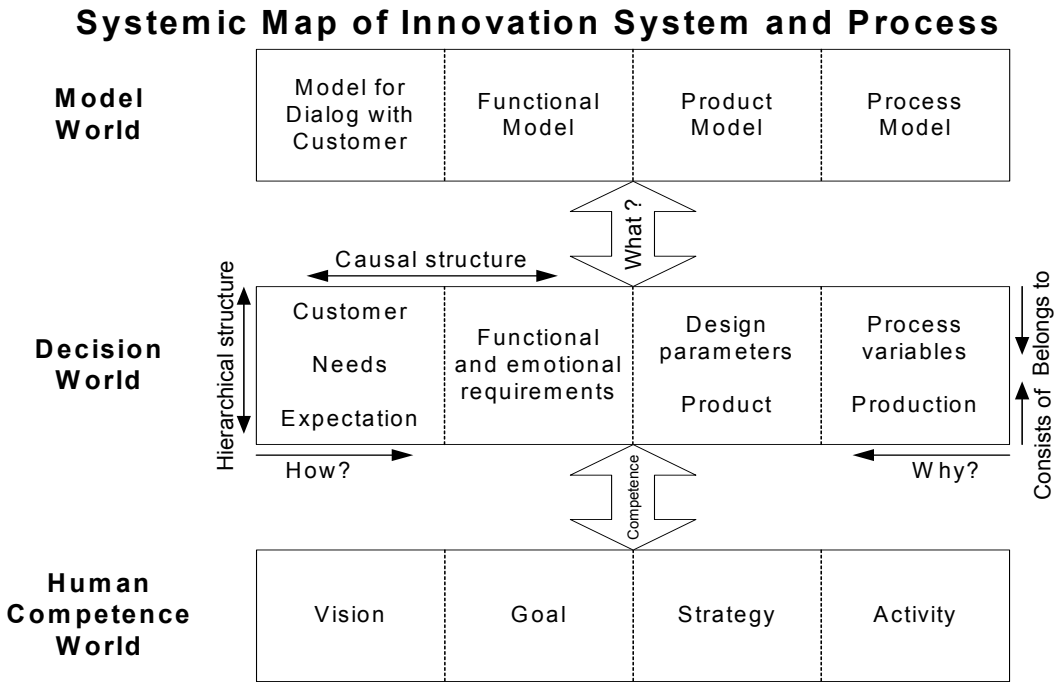

Figure 2. Systemic Map of Innovation System and Process.

Decision world

Nam Suh is proposing to see the design process as a mapping between four domains, Figure 3, [7], [8]. This interpretation is relevant for understanding the design process and useful for elaboration of the interactions between the domains. The design process is principally a decision process, where the objectives are defined from the needs and expectations of the stakeholders, primarily the customers, but also the shareholders, the employees and the society.

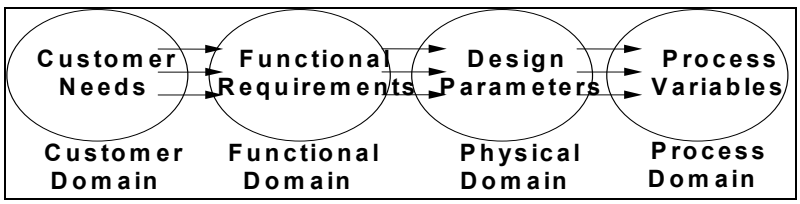

Figure 3. Design Domains.

A closer look at the logical nature of this process reveals two important orthogonal structures: the hierarchical structure vertically and the causal structure horizontally in Figure 2.

The hierarchical structure has to do with the inherent hierarchical nature of products. A product consists of modules, which consist of components, which consist of parts carrying features. The tree-structure is, in the ideal case, identical in the functional, design and process domains and the structure is defined by the words *consists of* downwards and *belongs to* upwards. Decomposing and composing within the domains illustrate vertical and hierarchical relationships.

The causal structure has to do with objectives and means, and is showing the connections between related positions in the hierarchical trees in adjacent domains. The words *how* and *why* are the horizontal guiding keys in this structure. Mapping between the domains exposes horizontal and causal relationships.

The existence of these two structures is the logical reason why we have to zigzag between the domains if we want to follow the connections between Functional Requirements, Design Parameters and Process Variables. In other words zigzagging, as in Figure 4**,** is to follow the logical nature of innovating products and processes and to meet defined and expressed goals**.**

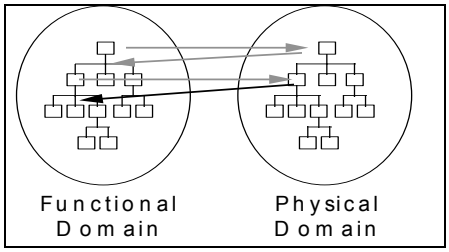

Figure 4. Mapping and decomposing by zigzagging.

According to the theory of *Concurrent Engineering,* design of the product and the process has to be integrated in order to secure product quality. In concurrent engineering we are integrating at least two design-objects as the product, the production system and/or the production process [13], [14], [15].

Human competence world

The decisions have to be taken by humans cooperating in the innovation process. It is also necessary to develop the human part of the industrial system in its widest meaning, in parallel to and within the planning of the entire business process. The qualitative part of this human system is very much equal to the competence of people involved. The ability/interest/desire to define goals and to make decisions is a prime core competence related to quality and productivity.

A good way to support the competence development in a company is to deal with concepts as *vision, goals, strategies* and *activities* vertically in the company**.** This dialogue is a good instrument to create coherence in the understanding of the business at different organizational levels in the company [16] [17]. It is also useful and interesting to note that the concepts *vision, goal, strategy* and *activity* in the human competence world, have the same conceptual meaning as *customer, function, design* and *process variable* in the decision world in Figure 2.

The competences needed for the new business process around the new products have to be defined and developed for and within the innovation process.

Model world

The model world is a part of the decision process and at the same time a necessary tool in the communication between humans and between humans and computers [18], [19], [20].

The models of products, modules, components, parts and processes have to be created in parallel to the decisions in the decision world. The Design Parameters have to be carried by features functioning to meet the Functional Requirements. Features are carried by parts, belonging to components, which are assembled into modules and products. The models are descriptions of products, modules, components, parts and features capable of answering *what*-questions, Figure 2**.** In this way we can get a complete picture by handling *why* and *how* questions as well as *what* questions in a connected and consistent way.

3. Business Systems and Processes

3.1 Industrial Company as a Business System

An industrial company, or a business unit within a company, can be regarded as a business system, which is composed of sub-systems and processes. The business sub-systems are representing different perspectives on the business, inside and outside the company, and can be denominated market, innovation, supply and service. Most of the activities for business development are carried out in the sub-system for business innovation, henceforth called the innovation system. But development activities are also carried out in the other business sub-systems (market, supply and service). In the innovation system therefore concurrent activities from the three other business sub-systems are included. This concurrent engineering is shown in the model in Figure 5 there the innovation system is over-lapping the market system, the supply system and the service system to some extent.

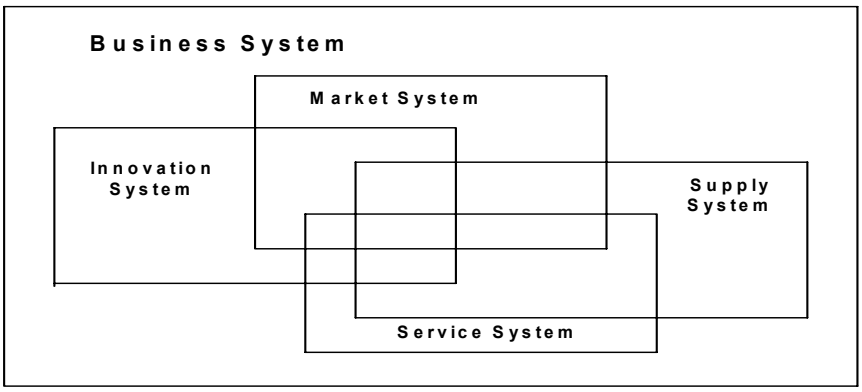

Figure 5. Model of Business System with four sub-systems.

The innovation system can be further decomposed into sub-systems, which in this paper are denominated product-market, product-function, product-design, product-supply and product-service according to different perspectives and structures of the product platform. By regarding these sub-systems as different views of the innovation system, and handling them as domains, theories and methods from the engineering design area can be utilized for business innovation including product platform development and product structuring.

3.2 Business Processes in an Industrial Company

In order to be competitive an industrial company needs to have effective business processes. A business process is an assembly of connected activities and is designed to create value for customers. In this paper the business process is composed of four sub-processes, which are denominated pre-development (process-for-technology), main development (process-for-market), order and delivery (process-for-customer), and use and maintenance (process-for-service) according to four phases in the product life cycle. Within these processes the activities are carried out.

Business innovation activities are performed in the business sub-processes for pre-development and main development. The innovation process is composed of these two sub-processes for business development (representing the product life phases time-to-technology and time-to-market) in Figure 6.

Business operation activities are executed in the business sub-processes for order and delivery (representing the product life phase time-to-customer) and for use and maintenance

(representing the product life phase time-to-service). These two business sub-processes can be called the production process and the maintenance process.

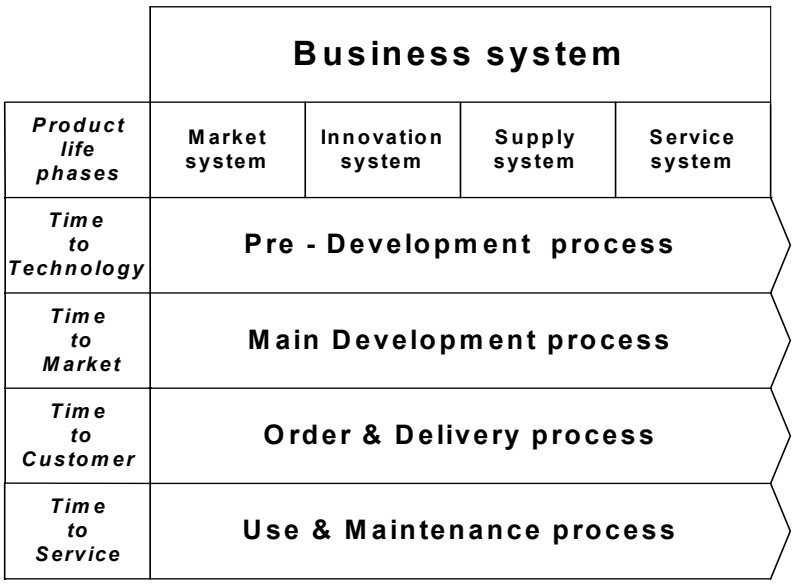

Figure 6. Model of Business System and Business sub-Processes.

3.3 Business Innovation System

Business development activities are performed in the business sub-system for innovation.
The innovation system can be decomposed into sub-systems, which in this paper are denominated product-market, product-function, product-design, product-supply and product-service.

The business system covers all four business sub-processes, but the innovation system covers only two of the sub-processes (for pre-development and main development). See Figure 7.

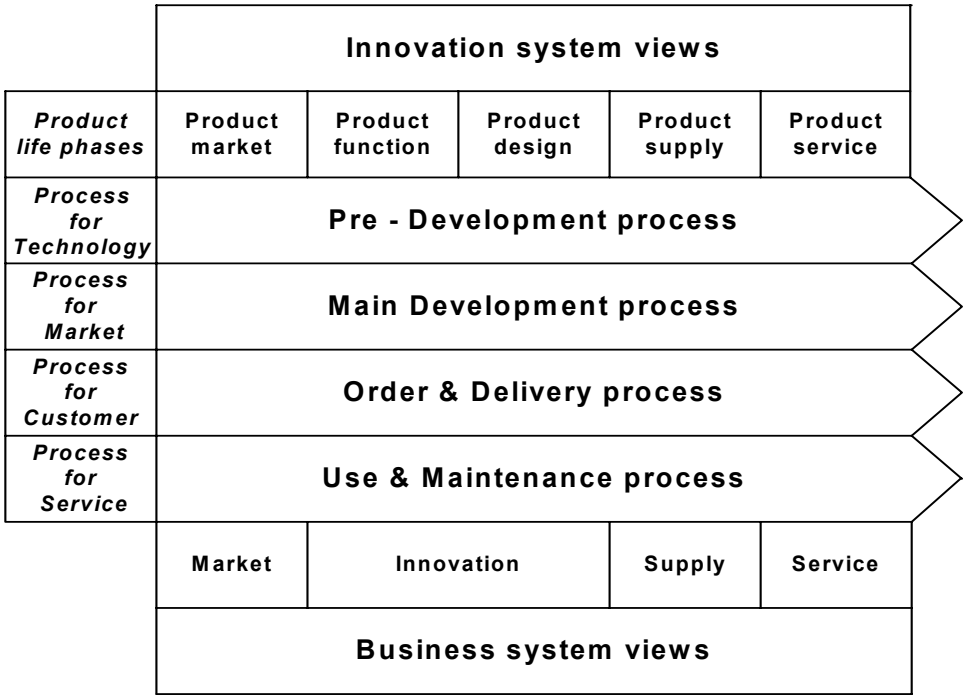

Figure 7. Model of Innovation System and Business System with different views.

3.4 Interaction Mechanism

The Theory of Domains, by Andreasen [2] [3], describes the design task as navigation in relation to a basic pattern, which is composed of causal relationship between the domains. The domain model can be regarded as a basic map, on which it is possible to chart the progress of the design task.

In the Axiomatic Design theory, by Suh [5], [6], [7], [8], the design process is seen as a mapping between four domains, customer, functional, physical and process domain, Figure 3. This interpretation is relevant for understanding the interactions between the domains and useful for elaboration of the interaction mechanism in this paper. Axiomatic design deals with the hierarchic nature of designs, which appears in the functional, physical and process domain as trees with more or less identical structures. The functional-, design- and process-trees grow throughout mapping between the domains and decomposing within the domains. The mapping between the domains creates the branches on each level. One whole level has to be mapped over all domains, before decomposition to the next level starts. This process, mapping between the domains and decomposing within the domains, is called zigzagging, Figure 4.

For the navigation between and within the domains (sub-systems) a design tool called *Interaction Mechanism* is described and used in this paper. The Interaction Mechanism is based on principles in the Theory of Domains and the theory of Axiomatic Design. The Mechanism can be used for innovation (interaction engineering) in the business system including transformation of information between the sub-systems and within the sub-systems. The transformations can be in form of translation, creation, elaboration, realization, composition, decomposition, constraint, validation, verification, change or improvement. The mechanism can be regarded as a navigation tool comparable with a compass with interaction instructions, Figure 8, [21], [22], [23].

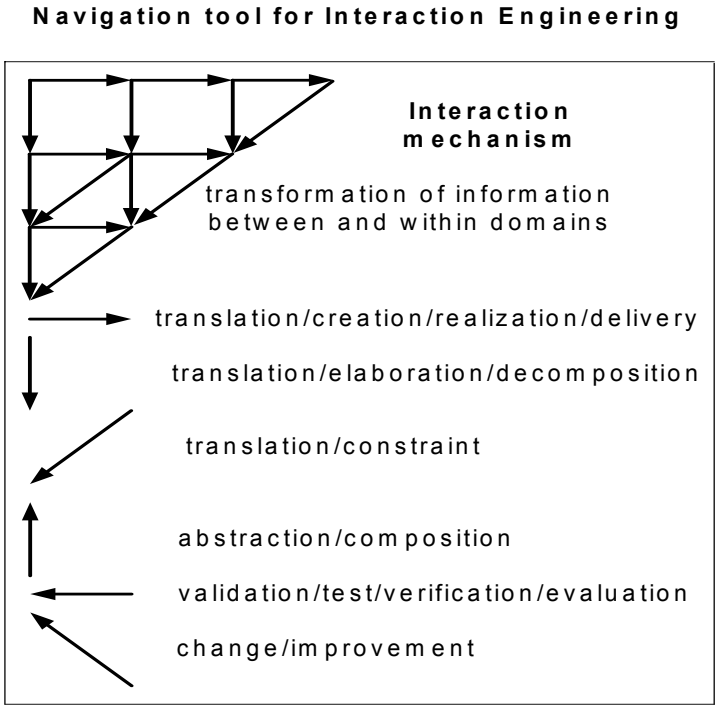

Figure 8. Mechanism for Interactions between domains and within domains.

3.5 Business Innovation

In this paper Business Innovation is considered as Innovation of Business systems and processes. Activities for business innovation are performed in the innovation system and the two sub-processes in the innovation process, pre-development and main development. The innovation system consists of sub-systems and by regarding these sub-systems as different views and handling them as domains, theories and methods from the engineering design area can be utilized for business innovation, sometimes called business (re) - engineering [1], [2], [3], [5], [6], [7], [8], [24], [25], [26].

The research approach is that Business Innovation can be regarded as a design task and following design objects, corresponding to parts of the product platform and represented by sub-systems in the innovation system in Figure 7, are set up:

- Product-market system (demand/offer structure)
- Product-function system (function/system structure)
- Product-design system (product/realization structure)
- Product-supply system (production structure)
- Product-service system (maintenance structure)

Design objects are also connected processes for business development and operation, which have to be designed, re-designed or re-used, Figure 6. Design is corresponding to decision-making in a design or innovation process using decision world, human competence world and model world in Figure 2, [12], [15], [28, [29].

Design for business operation, i.e. development of business systems and processes, can be done by interactions/transformations between sub-systems and sub-processes in the matrix of business system/process. Sub-systems and sub-processes are interrelated; results (outputs) from sub-processes are stored as information in structures of sub-systems, and information in structures are used as inputs to sub-processes. Interactions horizontally have causal relationships and interactions vertically have hierarchical relationships. Horizontal relations answer the questions *What, How* and *Why*, and vertical relations answer the questions *What, Consists of* and *Belongs to*, according to Figure 2.

Business systems and processes are designed by zigzagged mapping between the subsystems (domains) and sub-processes with the Interaction Mechanism. By stating the interactions, business sub-processes in Figure 7**,** can be developed and described with nouns and verbs for each process-step or activity. According to Figure 1 we first design the innovation process, which can be used for development or innovation of the product and its support systems. The innovation process is here consisting of two sub-processes, the pre-development process and the main development process. We start to develop the first development sub-process, the Process-for-Technology (PfT). Thereafter, the second development sub-process, the Process-for-Market (PfM), is developed based on the technology-process.

Example for development of the PfT- and PfM-processes with use of the Interaction Mechanism in Figure 9:

- PfT/Scope/Need is translated into PfT/Function Requirement,
- which is created into / realized (virtually) by PfT/Digital product model,
- which is realized (virtually) by PfT/Production simulation.
- PfT/Scope/Need is elaborated into PfM/Concept/Requirement, which is also translated from/constrained by PfT/Function Requirement.
- PfM/Concept/Requirement is translated into PfM/Function specification, which is also elaborated from PfT/Function Requirement and constrained by PfT/Digital product model.

- PfM/Function specification is created into/realized by PfM/Prototype, which also is elaborated from PfT/Digital product model and constrained by PfT/Production simulation
- PfM/Prototype is realized/produced by PfM/Prototype production, which is also elaborated from PfT/Production simulation.

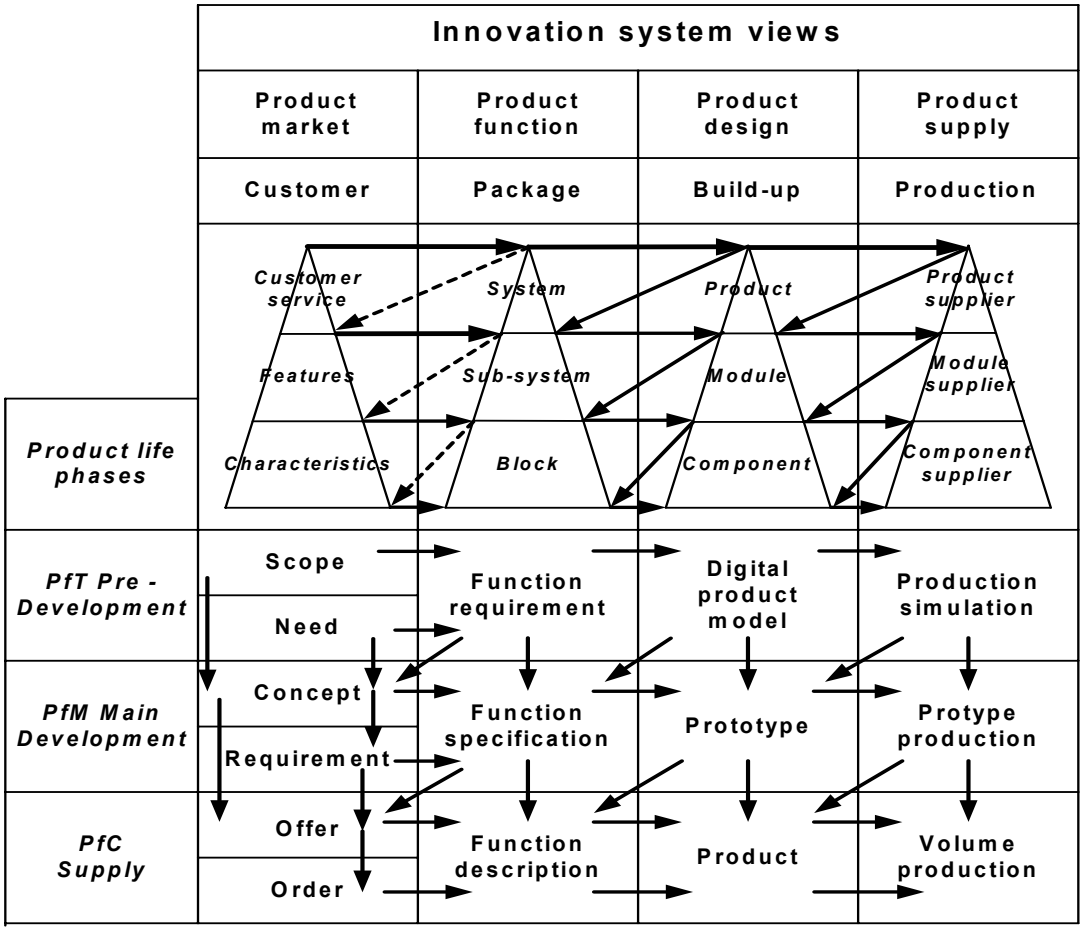

Figure 9. Model of Innovation System with structures, processes and interactions.

When we have developed the innovation process, we develop the production process, e.g. the Process-for-Customer, based on the Process-for-Market, concurrent with the product and the production system. We can also develop the maintenance process, the Process-for-Service, based on earlier processes and concurrently with the product and/or the production system.

When the business processes are designed, we can use or re-design them for development of the product platform in form of the sub-systems for product-market, product-function, product-design, product-supply and product-service. The Interaction Mechanism is then used for mapping between the domains (sub-systems) and decomposition within the domains.

Example for mechatronical product is shown in Figure 9:
- Start from top-level and walk over all domains.
- When decomposing within a domain, use information from adjacent levels and domains by translating, creating, realizing, constraining and so on.

The results from these interactions or activities in the business processes can form the hierarchical information content for the product platform and its business as market offer, function structure, product structure, supply structure and service structure. Product-service view is not included in Figure 9. All business sub-processes have to be run through (mapped

over all domains) and all hierarchical levels have to be decomposed/composed in order to develop the product and its support systems.

Business innovation covers the area from business and product idea to business operation and product maintenance, and includes customer demands and solutions. The main part of business innovation is development of the product platform and its support systems and processes. Product platforms are based on different perspectives of the business and include various product and support structures. Product variants and corresponding production systems are created and realized by configurations within the product platform.

4 Key conclusions

Business innovation is in this research study considered as innovation of business systems and processes including product platform development and product structuring. Business innovation is performed by interactions within and between the business sub-systems and the business sub-processes. Modelling of business systems and processes including product platforms and structures during four product life phases are presented.

The paper is elucidating that business innovation, including modelling and structuring of products, can be carried out by working in a systematic and structured way and by utilizing engineering design theories and methods. The models with the navigation tool for interactions are describing what activities should be performed in business innovation with product platform development and product structuring.

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